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NOTES

Noise Emission—A Part of Risk Assessment With a View to Machine Safety

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For specific machinery groups standards on International Organization for Standardization (ISO) or European Committee for Standardization (CEN) levels describe safety aspects, technical data, or test methods. Problems with the implementation of noise aspects in safety standards are discussed. The reduction of emissions from machinery (noise, vibration, radiation, hazardous substances) has to date clearly been almost neglected, due, it seems, to the unsuitable approach of classical risk reduction. The concepts of the ISO/IEC Guide 51:1999 (ISO, 1999), Standards No. EN 292 (CEN, 2000c, d), and the Directive of the European Parliament and the Council 98/37/EC (the so-called Machinery Directive) to reduce risks are compared and specific requirements to safety standards according to emission, especially of noise, are presented.

noise emission risk assessment safety of machinery

1. INTRODUCTION

It is known that machinery with low emissions of, for example, noise, vibration, radiation, hazardous substances, leads to low exposure for persons present at workstations, workplaces, and in the surrounding area (outdoor, indoor).

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Quiet products, that is, machines with low noise emission, constitute one of the specific objectives of occupational safety and health and environmental protection.

How can the goal of achieving quiet products be attained or what means are employed in the attempt to attain it? How can interest in this goal be aroused among the groups responsible and affected?

2. REGULATIONS FOR NOISE

1. Requirements are set for the user and the operator of machines. Noise immission and exposure limits are defined and a general obligation to reduce noise and to comply with the state of the art is laid down. It is expected that the user of machines and installations will purchase low-noise machines in order to meet the stipulations, thus also motivating manufacturers to design low-noise machines. This approach, however, has to date not worked, except in specific fields like household appliances, where low noise emission from machines has become a quality parameter.
2. Requirements are set for the manufacturer of machines In Europe there are European Union (EU) Directives for

   - Motor vehicles; these lay down measuring procedures and limits for noise emissions;
   - Outdoor machines; these describe noise emission measuring procedures and lay down labelling and, for a selected number of machines, limits for the emissions.
     In both cases the limits are laid down on the basis of extensive expert studies conducted by government or the EU Commission, or both.
   - Household appliances; these describe measuring procedures with regard to noise emissions (sound power level), and they provide for a noise emission declaration as part of the energy labelling for certain appliances.
   - All directly applicable machines (Directive of the European Parliament and the Council 98/37/EC, the so-called Machinery Directive); in particular in Annex I requirements are laid down for machines to prevent or minimise any risk arising to health and safety from the operation of machines. With regard to noise emissions specifically the manufacturer is obliged to reduce the noise emission at source to the lowest levels and provide a declaration on noise emission.

No limits are provided for; the nature of the declaration however is described in principle.

3. SAFETY REQUIREMENTS FOR MACHINES

In general, Annex I of the EU Machinery Directive (98/37/EC) contains the obligation to avoid and reduce hazards. In principle the following priorities apply in the reduction of hazards: elimination or minimisation of hazards (risk minimisation by means of structural measures), taking any protective measures still necessary, information on residual risk.

The technical details (requirements and measures, measuring and verification procedures, information on residual risk) concerning the implementation of these requirements are to be described in standards. Standards EN 292-1:2000 (European Committee for Standardization [CEN], 2000c), EN 292-2:2000 (CEN, 2000d), and EN 414:2000 (CEN, 2000e) present principles governing the description of safety[1] requirements in standards and describe their implementation (type A standards). Further standards describe measuring procedures and measures for specific hazards like noise (type B standards). Machine-specific safety standards (type C standards) contain safety requirements and measures, the measurement and verification procedure, and instructions for use; around 750 safety standards for every machine group are in the pipeline.

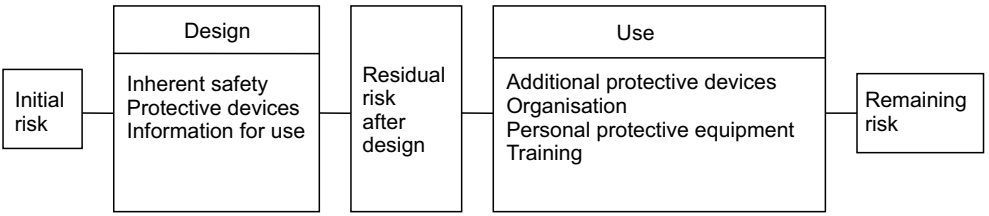

Figure 1. Risk reduction approach described in ISO/IEC Guide 51:1999 (ISO, 1999) and EN 292:2000 (CEN, 2000c, d; for the first three boxes).

The ISO/IEC Guide 51:1999 (ISO, 1999) gives guidelines on how to include safety aspects in standards, generally. Safety[1] is dealt with in standards in different forms in all areas of technology and for most products, processes, and services. With the increasing complexity of products, processes, or services entering the market, it is obvious that safety[1] has gained considerable

[1] Safety is understood as a general approach to health and safety.

importance in our contemporary world. There can be no absolute safety—some risk will remain, defined in this Guide and by the Machinery Directive (98/37/EC) as residual risk: Therefore a product, process, or service can only be relatively safe (Hosemann, 2001). The process of risk reduction is given for the producer and user (see Figure 1).

4. RISK REDUCTION ON MACHINES: SAFETY AND HEALTH

The objective, the priorities, and the approach for risk reduction on machines are described in a similar way in the EU Machinery Directive (98/37/EC), in the EN 292-1:2000 (CEN, 2000c) and ISO/IEC Guide 51:1999 (ISO, 1999).

The requirements can be classified roughly in three areas: hazards due to mechanical and electrical energy; hazards due to emissions (noise, vibrations, radiation, hazardous substances); hazards due to the violation of ergonomic principles.

Standards are to describe measures to be taken to enable the requirements of the EU Machinery Directive (98/37/EC) and ISO/IEC Guide 51:1999 (ISO, 1999) concerning risk minimisation to be satisfied (EN 1050:1997 [CEN, 1997e], EN 292-1:2000 [CEN, 2000c], EN 292-2:2000 [CEN, 2000d]).

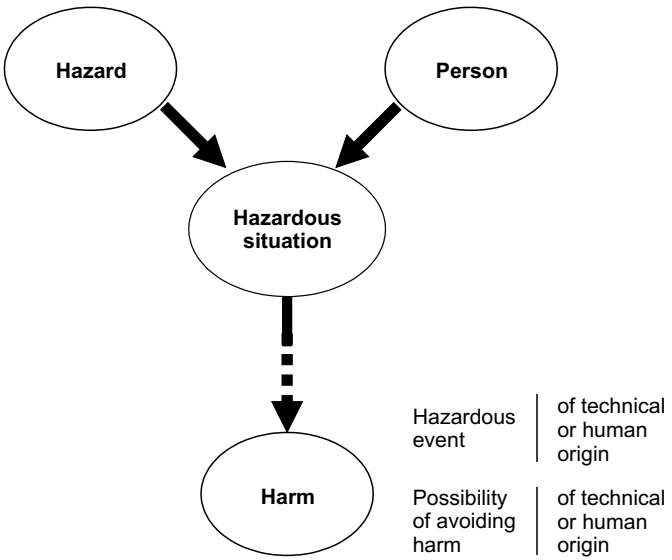

Figure 2. From hazard to harm.

Mechanical and electrical hazards can normally result in accidents (injuries) involving the operator or other persons present in the danger zone. The discussion and experience in the domain of machine-related safety engineering is dominated by the risk analysis of this accident pattern and the related risk reduction. Only when the hazard and a person coincide does a hazardous situation arise which may, under certain technical or personnel-related circumstances, lead to a hazardous event and hence to an accident. The risk of suffering damage (accident) arises from the probability of the occurrence and the severity of harm (Hosemann, 1999). Certain measures can be taken on all levels—in order to reduce the risk and avoid an accident (Figure 2). Safety requirements normally consist of specific measures to be applied.

5. RISK REDUCTION ON MACHINES: USING EMISSION VALUES (NOISE)

With emissions (noise, vibration, radiation) the situation is different. A distinction is drawn between the emission from the machine and the immission or exposure at the location where persons are present or could be present.

In the case of emissions the hazard is not seen in direct conjunction with potential operators and their behaviour, but rather it is assumed that, regardless of the behaviour of the individuals, injuries may occur to persons if exposed for a longer period to emissions both in the vicinity of the machine (operator) and at a greater distance from the machine. Harm is included in the risk analysis not in the form of a specific case or possibility thereof, but only globally in principle, as a potential risk which could arise from the emission (Lazarus & Zimmermann, 1998).

This means that we have to follow a concept in which two kinds of quantities are to be defined (Lazarus et al., 1996): (a) quantities for which only the manufacturers can be and are responsible, quantities that describe the radiation of the machine and are relevant to the exposure, and quantities with which the risk analysis for the machine can be carried out; and (b) quantities for which the users are responsible, quantities that describe the exposure, and quantities with which the risk analysis at the workplace can be carried out.

This concept is applied for noise in some standards: to determine noise emission (Standards No. EN ISO 12001:1997 [CEN, 1997a], EN ISO 3740:2000 series [CEN, 2000a], EN ISO 11200:1995 series [CEN, 1995a], EN 1746:1998 [CEN, 1998]), to estimate by means of the noise emission values the immission and exposure (see Standards No. EN ISO 11690-1:1997

[CEN, 1997c], EN ISO 11690-2:1997 [CEN, 1997d], EN ISO/TR 11690-3:1999 [CEN, 1999]) and determine, for example, the risk of hearing loss (see ISO 1999:1990 [ISO, 1990]).

The manufacturer. The manufacturers use only the emission values for the risk analysis of their machines and do not determine the immission or exposure value.

Two appropriately defined noise emission values are (a) the sound power level (L_{WA}, determined after Standard No. EN ISO 3740:2000 series [CEN, 2000a]); (b) the emission sound pressure level at the workplace (L_{pA}, determined after Standard No. EN ISO 11200:1995 series [CEN, 1995a]).

These emission values are determined in accordance with standards in such a way that, on the one hand, they describe the sound generation of the machine, that is, they are purely characteristics of the machine. On the other hand they are the major factor for the level of the immission in the vicinity of the machine (L_{pA}), that is, at the workplace, and regarding L_{WA} at a greater distance from the machine, where other employees may be working or other people live in the environment.

This means that for the risk assessment an evaluation of the emission values (L_{WA}, L_{pA}) is sufficient, because lower emission values result in a lower noise immission and exposure, thus lowering the risk.

The user. To carry out a risk analysis for a workplace the occupational safety specialist normally first determines immission or exposure as A-weighted continuous sound pressure level or rating level. Second, he or she assesses whether the measured sound pressure level exceeds any noise limits (Council Directives 86/188/EEC, 2003/10/EC), or is too high compared with target values in standards and the state of the art. As a rule it is not necessary to determine potential hearing loss or other impairment.

Any risk reduction at the machine should start with defining objectives for the identified hazard. Then safety requirements must be established. As is stated at the end of section 4, safety requirements for preventing accidents (injuries) normally consist of specific measures. But other safety requirements, which only refer to the objectives, are possible and necessary for reducing emissions. Such safety requirements can be, for example, the time until the brake works must be shorter than 1 s, the temperature of that machinery surface must not exceed 60 °C, and noise emission should be lower than 70 dB(A) for the emission sound pressure level at the workplace. Additionally safety design and protective measures must be implemented to fulfil these safety requirements. The advantage is that the means to fulfil the objectives are free. The designer has to take into consideration all these

requirements (Reudenbach, 1999). To control and reduce emission, emission values must be determined and assessed by the manufacturer.

6. EMISSION VALUES FOR PRODUCTS

With reference to the requirements specified in EC product directives, and in particular the Machinery Directive (98/37/EC), and with the manufacturer in mind, two principles must be taken into account: reducing risk to the lowest possible level (principle of risk minimisation), informing the user of existing residual risk (principle of user information).

For this purpose emission that causes risk for safety and health should be quantified.

In order to be able to identify and indicate emissions such as noise, vibrations, hazardous substances, and radiation, certain conditions have to be fulfilled (see Angaben zu Emissionen in Maschinennormen, 2000):

- The measuring procedures, which already exist to a large extent (type B standards), are to be specified in type C standards for the different groups of machinery.
- Representative conditions of operation for measuring emission are to be defined.
- Measurements are to be carried out on the basis of points 1 and 2.
- Measured emission data must be collected.
- The data must be gathered for each type of machinery and presented as a distribution of the measured values (orbit of measured values).
- The distribution of the measured values must be integrated into the respective C standards. They are to be considered as reflecting the state of the art for the particular type of machinery and as indicative values that support designers in their efforts to reduce the risks.

7. SAFETY REQUIREMENTS FOR MACHINES WITH LOW EMISSIONS

What is the best strategy to achieve machines with low emission, as required according to various standards or directives? The following should be achieved:

- Tolerable risk, that is, risk that is accepted in a given context (ISO/IEC Guide 51:1999 [ISO, 1999]);
- Adequate risk reduction, at least in accordance with legal requirements and under consideration of the current state of the art (Standard No. EN 292-1:2000 [CEN, 2000c]);
- Reduction of hazards to the lowest practical level (Standard No. EN 292-1:2000 [CEN, 2000c]);
- State of the art taken into account (Council Directive 89/391/EEC);
- Risk reduction to the lowest level taking into account technical progress and availability of means (Council Directive 89/392/EEC, Annex I).

In order to reduce risks it is usual practice in safety engineering, to specify adequate measures in standards, which then have to be followed by the design engineer (covering grid, two-hand controls, etc.). The effectiveness of such measures can normally be checked by visual inspection. The safety requirements according to the safety standard are satisfied if the measure described has been included in the machine.

For risks caused by emission it is convenient not to lay down specific measures but to use measurable quantities and to define safety requirements in order to control and assess reduction measures.

It is generally appropriate to be oriented more towards the objectives than to specific measures.

For noise, like for other emissions, this means

- It is possible to lay down and propose specific reduction measures. But such measures can only be verified by measuring the emission; visual inspection alone is not sufficient, because it is not known if the measures used work. Moreover these measures do not assure whether the emission has been adequately reduced, that is, whether the state of the art has been attained. Fixing specific measures in standards limits the scope for creativity and room for manoeuvre for the manufacturer.
- It is also possible to lay down noise emission limits (as given for some machines in the Directive of the European Parliament and the Council 2000/14/EC) classified in terms of machine parameter categories (e.g., categories of mechanical power). Specialists could fix these relevant limiting emission values on the basis of technical conditions for each specific machine group. This is not possible, however, without conducting large-scale, machine-specific investigations. The result would be highly static, which, in view of the inherent dynamic process (ongoing development), can only reflect current status. Such investigations would therefore have to be repeated at specific intervals.

Laying down noise reduction measures or fixing noise limits is not a practical way to achieve low-noise machines. This of course also applies for the 750 different machine types covered by the Machinery Directive (98/37/EC).

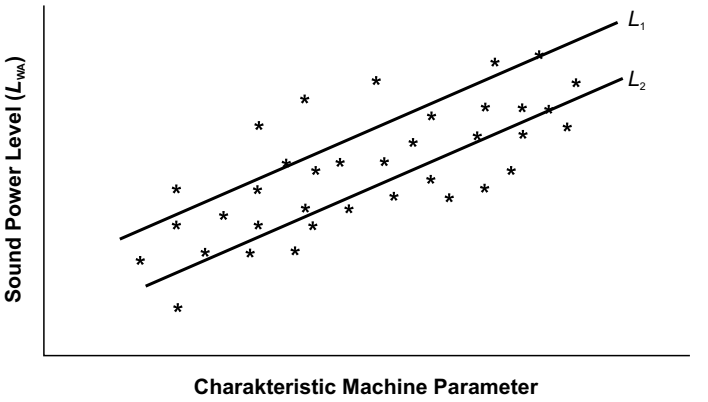

Figure 3. Comparative emission data (according to Standard No. EN 292-1:2000 [CEN, 2000c]) for noise: Noise control performance (according to Standard No. EN ISO 11689 [CEN, 1997b]) as sound power level (L_{WA}) over characteristic machine parameter (frequent: power). *Notes.* L_1 ~ 70–90% of cumulative frequency, L_2 ~ 10–30% of cumulative frequency, machines with $L_{WA} > L_1$ have a low noise-control performance, machines with $L_2 < L_{WA} < L_1$ have an average noise-control performance, machines with $L_{WA} < L_2$ have a high noise-control performance.

The basis for assessing the amount of risk reduction with respect to emissions by technical measures are the emission values as determined by standardised methods. The methods for declaring the two quantities of noise emission (L_{WA}, L_{pA}, see section 5) has been developed and laid down as basic standards (Standards No. EN ISO 3740:2000 series [CEN, 2000a], EN ISO 11200:1995 series [CEN, 1995a], EN ISO 4871:1996 [CEN, 1996]). The machine specific standards (C type) define on basis of these basic standards detailed methods for determining noise emission for all types of machines (operation conditions, workstations, etc.). The current range of emission values is given by the comparative emission data (Standards No. EN 292-1:2000 [CEN, 2000c] and EN ISO 11689:1997 [CEN, 1997b], Figure 3). This is a set of emission values of the same type of machines with the purpose of comparison. Thus manufacturers can assess where the emission of their machine lies; whether it belongs to those machines with higher noise emission values or to those with a lower noise emission. Furthermore users can assess whether the machines they intend to buy are relatively quiet or not. With this tool the authorities can also derive and assess the state of this art.

On the basis of such a representative range of noise emission values (also denoted as noise control performance in Standard No. EN ISO 11689:1997 [CEN, 1997b]), so-called indicative values may be drawn up. These may be identical to the regression lines L_1 or L_2 of EN ISO 11689:1997, which describe different noise control performances. Thus machines with emission values below L_1 can be interpreted as machines with common and simple noise reduction measures, whereas machines with emission values lying below L_2 not only reflect technical progress but also show that measures primarily at source, together with measures in the transmission path within the machines (e.g., enclosure) have been applied (see Standards No. EN ISO 11688-1:1995 [CEN, 1995b] and EN ISO 11688-2:2000 [CEN, 2000b]). Such values, for example, are given for emission sound pressure values (as L_2 values) for pre-formed rigid container packaging machines (Standard No. EN 415-2:2000 [CEN, 2000f]) and chain saws (Figure 4).

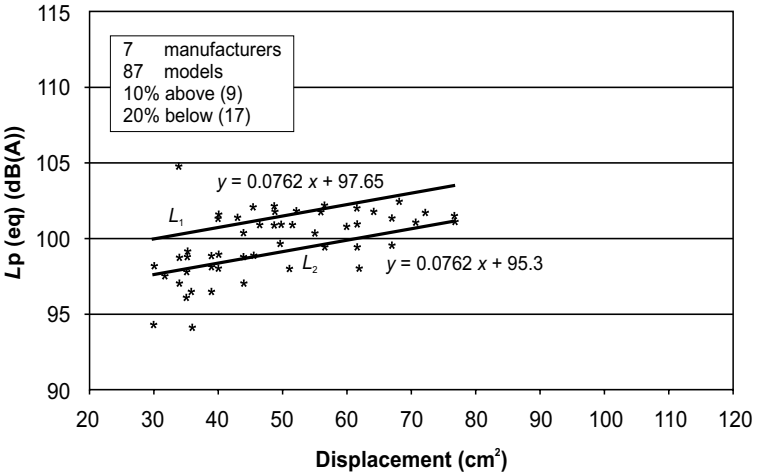

Figure 4. Emission sound pressure level for chain saws with operating conditions defined according to Standard No. ISO TS 22520:2001 (ISO, 2001).

8. CONCLUSION FOR NOISE EMISSION

The EU Machinery Directive (98/37/EC) not only requires a noise declaration, but it also requires that the machine must be designed and constructed in such a way that hazards due to noise emission are reduced to the lowest level achievable, taking into account technical progress and the available means of noise reduction primarily at source.

For the noise declaration, clauses are now being drawn up in the safety standards (annexes or noise test codes) with regard to the determination and declaration of noise emissions.

However, as long as safety standards do not contain a range of comparative emission data (with or without a links to specific measures), the requirement in standards to specify more closely general objectives to reduce noise emission is not satisfied. What does the lowest level achievable mean in the case of a specific machine? This can only be documented as a relatively low emission value within the range of emission values of the same type of machine.

In short,

- For safety engineering it is common practice to prevent accidents by implementing specific measures at all levels of the application. The scale for assessing the reduction of risks is the measure itself.
- For emissions, a different approach is necessary. Because the situation of exposure at the user's location is more or less unknown for the manufacturer, the manufacturer has to focus on the emission of the machine. In this case therefore the scale for assessing the reduction of the risk is not the measure itself, but the emission value in relation to other machines of the same kind. Comparative emission data must therefore be given in safety standards on the basis of standardised methods.

Any requirement relating to technical measures to be observed in concrete form obstructs technical progress, restricts the design engineer's possibilities, and does not do away with the need for subsequent acoustic measurements.

An orientation towards emission values however is

- indispensable, because only in this way can the effectiveness of noise reduction measures be shown,
- possible because relevant data is available,
- supportive for the idea of comparing emission values of machines of the same kind,
- useful because emission values make it possible to characterise the (relative) state of noise reduction technology for a specific machine group,
- supportive for the promotion of exemplary noise reduction measures,
- useful for estimating immission or exposure.

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